

Proposed Sustainability and the Internet Proposed Research GroupA. Gallego Sanchez
Internet-Draft T-Systems

Intended status: Informational

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Expires: 23 April 2026

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October 2025

Path Energy Traffic Ratio API (PETRA) Augmented
draft-malja-sustain-petra-augmented-01

Abstract

This document describes an API to query a network regarding its Energy Traffic Ratio and other energy-related metric for a given network path.

About This Document

This note is to be removed before publishing as an RFC.

The latest revision of this draft can be found at <https://galledohm.github.io/draft-malja-sustain-petra-augmented/draft-malja-sustain-petra-augmented.html>. Status information for this document may be found at <https://datatracker.ietf.org/doc/draft-malja-sustain-petra-augmented/>.

Discussion of this document takes place on the Proposed Sustainability and the Internet Proposed Research Group Research Group mailing list (<mailto:sustain@irtf.org>), which is archived at <https://mailarchive.ietf.org/arch/browse/sustain/>. Subscribe at <https://www.ietf.org/mailman/listinfo/sustain/>.

Source for this draft and an issue tracker can be found at <https://github.com/galledohm/draft-malja-sustain-petra-augmented>.

Status of This Memo

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1. Introduction

Sustainability is becoming one of the major societal goals for the next decade, and networks are one of the major consumers of energy nowadays. Sustainability of network services is thus one of the forefronts of innovation and action from network service stakeholders, involving manufacturers, operators and customers. In this line, there is a shared goal of achieving better energy awareness.

As with any other network metric, the energy traffic ratio could be collected from the underlying network infrastructure. However, there is not a common or single definition of energy metrics towards network consumers so that they can be uniformly reported, particularly in heterogeneous network scenarios. This document introduces an API to query networks about Energy Traffic Ratio.

Beyond simple efficiency indicators such as watts per gigabit, network stakeholders are increasingly interested in richer sustainability information, such as carbon intensity, energy, power usage effectiveness (PUE), idle energy draw, and transmission losses. These additional metrics allow more informed decision-making in contexts such as service routing, green SLA negotiations, and sustainability reporting.

2. Conventions and Definitions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Path Energy Traffic Ratio API (PETRA)

This document describes an API to query a network about the Energy Traffic Ratio for a given path. It takes as input the source and destination of a path along with the traffic throughput between and returns energy information related to the traffic on the path. This is energy computed by the infrastructure that is dynamically part of the traffic path. The API is agnostic to the actual hops and underlying infrastructure that enables a path, which might change transparently to the API. This document only describes the API, the computation of the energy information to return is out of the scope of this document.

The API can return a variety of energy-related parameters to provide a complete view of path sustainability. These include: base energy efficiency indicators, energy mix, renewable energy contributions, and standby or idle consumption.

Furthermore, the PETRA's energy parameters complement ongoing work on green service intents [I-D.irtf-nmrg-ibn-usecases], enabling customers to express sustainability objectives such as energy consumption thresholds, renewable energy usage, and carbon intensity limits. PETRA provides the underlying energy measurement interface necessary for providers to fulfill, assure, and report on these green intents. Moreover, by exposing detailed energy and carbon-related parameters, PETRA can allow intent translation components to map green service objectives into network resource allocation and path selection decisions.

3.1. Energy Information

This API allows to return a number of energy attributes associated with the path and the traffic. Currently the parameters that could be returned as energy information as part of the query are:

- * ***Watts per Gigabit:** How many Watts are consumed per Gigabit of traffic traversing the path.
- * ***Carbon Intensity:** How much carbon emissions are generated as a consequence of the energy consumed.
- * ***Energy Mix (%):** Percentage of energy used in the path that comes from different energy sources (e.g., solar, wind, biomass, nuclear, fossil fuel).
- * ***Greenness Degree (%):** The aggregated percentage of energy consumed on the path that comes from renewable sources. Useful to rank and select paths based on renewable energy usage.
- * ***Sustainability Score (01):** Composite metric combining greenness degree and energy efficiency (Watts per Gigabit), calculated as $(\text{Greenness}/100) \times 1/(1 + \text{Watts per Gigabit})$. Higher values indicate more sustainable, efficient paths.
- * ***Power Usage Effectiveness (PUE):** The ratio of total facility power consumption to the power consumption of networking/IT equipment.
- * ***Transmission Loss (%):** The percentage of energy lost along the path due to transmission inefficiencies.

- * **Idle Energy Draw (Watts):** The amount of energy consumed by the path infrastructure when idle or under negligible load.

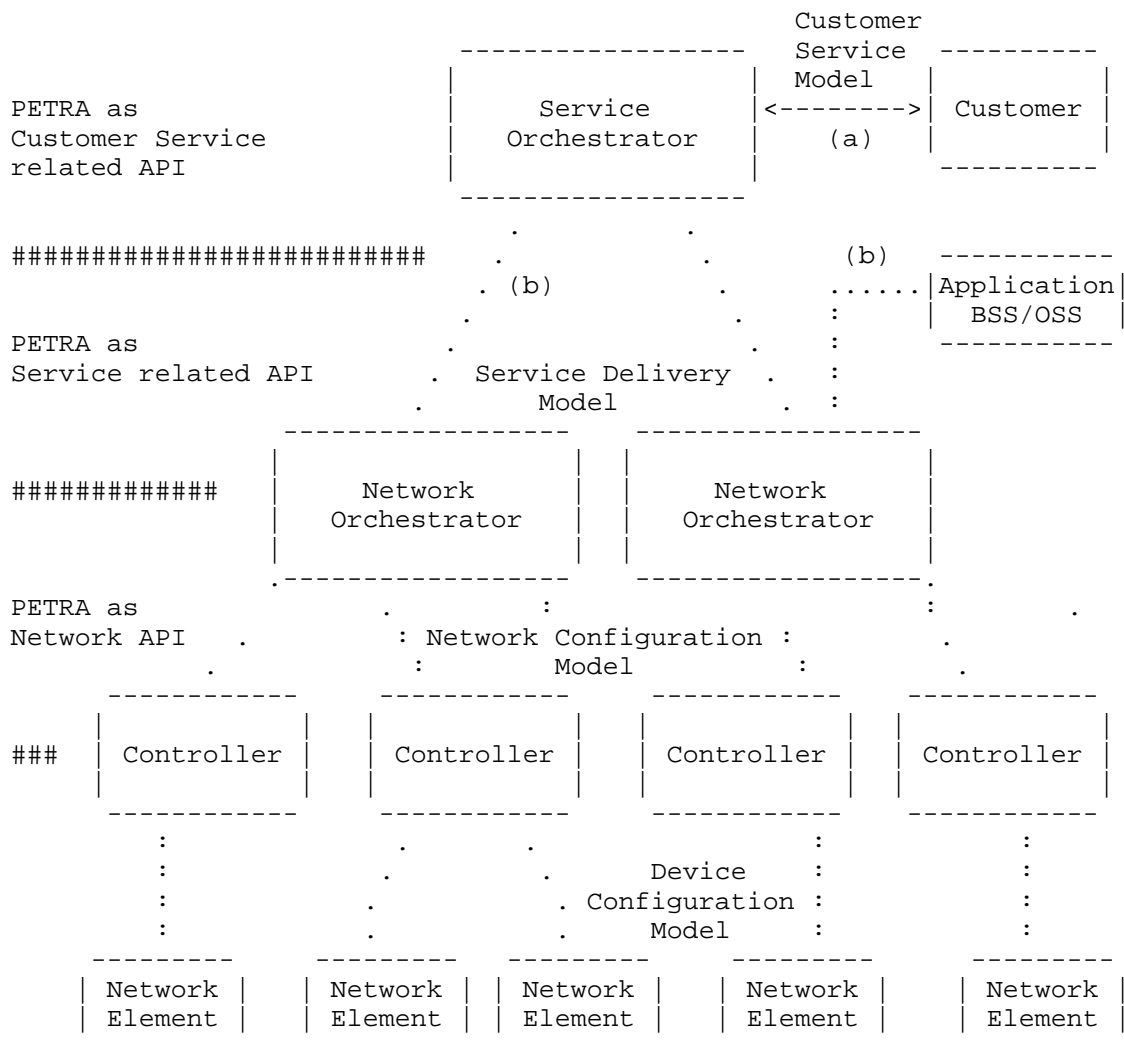
These metrics are OPTIONAL, and an implementation MAY support a subset depending on available measurement capabilities.

3.2. Recursive Usage

The API is envisioned in such a way that could be used recursively. That means, subpaths could report their energy consumption using PETRA and such energy consumption could be aggregated and reported for the overall path also using PETRA.

Similarly, this API could be (recursively) used to provide energy information according to the definition of Service Models in an SDN context as described in [RFC8309]. In that case, using Figure 3 in [RFC8309] as reference, PETRA could be used between the Controller(s) and the Network Orchestrator(s), between the Network Orchestrator(s) and the Service Orchestrator, and between the Service Orchestrator and the Customer(s).

While considering recursive usage, the aspect of double-counting shall also be taken into consideration. Double counting refers to the fact of counting more than once the same energy consumed. Organizations using PETRA in a recursive manner need to take appropriate measures to ensure no double-counting occurs across recursive calls to the API.



4. YANG Module

This is a possible definition of PETRA as a module following the YANG specification [RFC6020].

4.1. Module Structure

```

module: irtf-petra
  +--rw energy
    +---x query
      +---w input
        | +---w src-ip          ietf-inet-types:ip-address
        | +---w dst-ip          ietf-inet-types:ip-address
        | +---w throughput      uint32
      +--ro output
        +--ro (result)?
          +--:(success)
            +--ro success
              +--ro watts-per-gigabit?  decimal64
              +--ro carbon-intensity?    uint32
              +--ro energy-mix*          -> list of sources and percentages
              +--ro greenness-degree?    decimal64
              +--ro sustainability-score? decimal64
              +--ro pue?                 decimal64
              +--ro transmission-loss?   decimal64
              +--ro idle-watts?          decimal64
          +--:(invalid-address)
            +--ro invalid-address

```

4.2. Module Definition

```

module irtf-petra {
  yang-version 1.1;
  namespace "urn:irtf:params:xml:ns:yang:irtf-petra";
  prefix irtf-petra;

  import ietf-inet-types {
    prefix ietf-inet-types;
  }

  organization
    "";
  contact
    "";
  description
    "Initial YANG rendition of the PETRA Energy API, v1.0.1

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```

(<https://trustee.ietf.org/license-info>).

This version of this YANG module is part of RFC XXXX (<https://www.rfc-editor.org/info/rfcXXXX>); see the RFC itself for full legal notices.

The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED', 'MAY', and 'OPTIONAL' in this document are to be interpreted as described in BCP 14 (RFC 2119) (RFC 8174) when, and only when, they appear in all capitals, as shown here.

";

/*

If you have an implementation of this YANG module, you could access it like something this over RESTCONF:

```
$ curl --location --request POST \  
  'https://localhost:8008/restconf/operations/energy/query' \  
  --header 'Content-Type: application/yang-data+json' \  
  --user 'admin:admin' \  
  --data-raw '{  
    'input' : {  
      'src-ip': '10.10.10.10',  
      'dst-ip': '10.20.20.20',  
      'throughput': '40'  
    }  
  },'  
}
```

And if all goes well, you might receive (besides all the HTTP headers) a reply body with something like this:

```
{  
  'output': {  
    'success': {  
      'watts-per-gigabit': '191.855',  
      'carbon-intensity': '108'  
    }  
  }  
}  
*/
```

```
revision 2025-10-06 {  
  description  
    "Extended PETRA YANG module with richer input parameters  
    and additional energy/sustainability metrics.";  
  reference
```



```
    "RFC XXXX: ...";
}

// ===== Groupings =====

grouping query-parameters-g {
  description
    "Common input parameters for energy path queries.";

  leaf src {
    type inet:ip-address;
    mandatory true;
    description
      "Source IP address for the path.";
  }

  leaf dst {
    type inet:ip-address;
    mandatory true;
    description
      "Destination IP address for the path.";
  }

  leaf throughput {
    type decimal64 {
      fraction-digits 2;
    }
    units "Gbps";
    description
      "Throughput of the traffic for which the path energy ratio is calculated.";
  }

  leaf measurement-interval {
    type uint32;
    units "seconds";
    description
      "Optional measurement interval (duration) for the query.
      If omitted, defaults to instantaneous or most recent data.";
  }

  leaf recursive {
    type boolean;
    default "false";
    description
      "Whether the query should be expanded recursively across
      multiple administrative domains (if supported).";
  }
}
```

```
grouping energy-metrics-g {
  description
    "Grouping for query result metrics.";
  leaf watts-per-gigabit {
    type decimal64 { fraction-digits 3; }
    units "W/Gb";
    description "Watts consumed per Gigabit transmitted";
  }
  leaf carbon-intensity {
    type uint32;
    units "gCO2e/kWh";
    description "Grams of CO2 equivalent per kilowatt-hour consumed";
  }
  list energy-mix {
    key "source";
    description
      "Percentage contribution of each energy source to the total energy used on the
path.";
    leaf source {
      type enumeration {
        enum solar;
        enum wind;
        enum hydro;
        enum nuclear;
        enum coal;
        enum gas;
        enum biomass;
        enum other;
      }
      description "Type of energy source.";
    }
    leaf percentage {
      type decimal64 { fraction-digits 2; }
      units "%";
      description "Percentage of path energy from this source.";
    }
  }
  leaf greenness-degree {
    type decimal64 { fraction-digits 2; }
    units "%";
    description
      "Aggregated percentage of energy from renewable sources.";
  }
  leaf sustainability-score {
    type decimal64 { fraction-digits 3; }
    description
      "Composite metric combining greenness degree and efficiency.
      Suggested formula: (Greenness/100) × 1/(1 + Watts per Gigabit).";
  }
}
```

```
    leaf pue {
      type decimal64 { fraction-digits 2; }
      description
        "Power Usage Effectiveness: ratio of total facility energy to IT/networking en
ergy.";
    }
    leaf transmission-loss {
      type decimal64 { fraction-digits 2; }
      units "%";
      description
        "Energy lost in transmission as percentage of total energy input.";
    }
    leaf idle-watts {
      type decimal64 { fraction-digits 3; }
      units W;
      description
        "Energy consumed by the path infrastructure when idle.";
    }
  }

// ===== PETRA Container =====

container energy {
  description
    "PETRA API top-level container for energy queries.";

  action query {
    description
      "Query the network for energy consumption and
      sustainability metrics along a given path.";

    input {
      uses query-parameters-g;
    }

    output {
      choice result {
        description
          "Result of the PETRA query.";

        container success {
          description
            "Successful query returning energy metrics.";
          leaf timestamp {
            type yang:date-and-time;
            description
              "Time when the energy data was measured or aggregated.";
          }
          leaf aggregation-level {
```

```
    type enumeration {
        enum path;
        enum subpath;
        enum site;
        enum facility;
    }
    description
        "Level of aggregation of reported data.";
}
container metrics {
    uses energy-metrics-g;
    description
        "Collection of energy and sustainability metrics.";
}

container invalid-address {
    description
        "Invalid source or destination IP address supplied.";
}

container unsupported-metric {
    description
        "The requested metric is not supported by this implementation.";
}

container insufficient-data {
    description
        "The system could not collect sufficient data for the query.";
}
}
}
}
}
```

5. Security Considerations

In order to mitigate security risks, the PETRA API should implement the necessary mechanisms for authentication, secure data transfer and privacy preservation. On the other hand, in order to prevent denial of service attacks, new subsequent similar requests could be silently ignored during periods or time, or even requests from the same client could be filtered to prevent system (i.e., controller or orchestrator) affection.

6. IANA Considerations

This document has no IANA actions.

7. References

7.1. Normative References

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7.2. Informative References

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Acknowledgments

Kudos to Elis Lulja for his help with the OpenAPI specification in early versions of this draft. Thanks to Fernando Sanz Garcia and Lori Jakab for their help and support on this work.

The contribution of A. Gallego Snchez to this document has been partially supported by the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation project Sustain6G (Grant Agreement no. 101191936).

The contribution of L.M. Contreras to this document has been partially supported by the Smart Networks and Services Joint Undertaking (SNS JU) under the European Union's Horizon Europe research and innovation projects 6Green (Grant Agreement no. 101096925) and Exigence (Grant Agreement no. 101139120).

Appendix A. Use Cases

This section describes some use-cases where this specification might be useful.

A.1. SD-WAN

Software-Defined Wide-Area Networks (SD-WAN) have become a common way for enterprises to provide cost-effective connectivity across their different geographically distributed sites. Typically, SD-WAN deployments operate as an overlay network that is established on top of an existing underlay connectivity network. One aspect to consider is that in many SD-WAN production deployments the operator of the overlay network and the operator of the underlay network are different organizations.

This poses an additional challenge when trying to derive sustainability metrics. Even if the underlay network is instrumented to collect energy data, this data is opaque to the operator of the overlay network which has no access to underlay information. While operators of underlay networks offer certain general network metrics to overlay operators, no interface has been defined to allow the overlay operator to query the underlay network for energy information.

In this context, the PETRA specification presented in this document enables the operator of the SD-WAN network to coordinate with the underlay operator to capture sustainability data. This in turns opens further use-cases, from observability and reporting to potentially overlay policies based on underlay energy data, further enabling an overall more sustainable operation of the network.

In addition to energy considerations in SD-WAN deployments, PETRA can also be leveraged for broader energy-aware service routing. In this context, network controllers and service orchestrators—such as SD-WAN controllers, transport SDN controllers, 5G slice orchestrators, or multi-domain service orchestrators—can use PETRA metrics not only to balance latency, throughput, or load, but also to optimize path selection according to sustainability objectives. For example, paths with the lowest carbon intensity or the highest share of renewable energy in their energy mix could be preferred, enabling service differentiation where “green paths” are explicitly prioritized. This brings a paradigm where routing decisions are jointly driven by network performance and environmental impact.

A.2. Multilayer Energy Management

The concept of multilayer L3-L1 collection involves integrating data from different network layers to provide a comprehensive view of network operations. The use case of multilayer involves collecting and correlating data from Layer 3 (network layer) down to Layer 1 (physical layer). This multilayer approach allows for better network performance, optimization, and troubleshooting by providing end-to-end visibility.

Leveraging PETRA API for multilayer L3-L1 collection use case enhances energy management by providing comprehensive visibility, enabling optimization, and supporting proactive management. This makes PETRA a useful tool for more accurate, efficient and effective energy management in modern networks.

A.3. SLA Negotiation for Green Services

Another use case for PETRA could be the negotiation of green Service Level Agreements (gSLAs) between operators and enterprise customers. By exposing PETRA-derived metrics such as renewable energy percentage, carbon intensity, or sustainability scores, providers can offer differentiated SLAs that explicitly include environmental targets. This enables customers to select network services not only based on performance guarantees, but also on their environmental footprint, for example requesting that at least 60% of traffic be carried over renewable-powered infrastructure. Such gSLAs empower customers to align their digital services with corporate sustainability goals and reporting requirements, while operators can use PETRA as the trusted source of verifiable energy data.

gSLAs can be negotiated using customer-expressed green intents that specify objectives such as maximum energy consumption, minimum energy efficiency, carbon emission limits, and renewable energy usage [I-D.irtf-nmrg-ibn-usecases]. PETRA's metrics, including watts per gigabit, carbon intensity, and energy mix, provide essential measurements to translate these intents into network configurations and to monitor compliance during service operation. The lifecycle of green intents, encompassing fulfillment and assurance phases [RFC9315], can be supported by PETRA through its capability to deliver real-time energy metrics for translation into network policies and subsequent monitoring and validation.

Appendix B. Requirements for Energy Efficiency Management

The document Framework for Energy Efficiency Management [I-D.belmq-green-framework] describes a framework that comprises a controller element. In that document, the tasks of the controller are defined as "collection, compute and aggregate". In the context of that framework, the controller could also expose PETRA to offer path-related energy information. The figure below updates the one present in [I-D.belmq-green-framework] to add an additional interface (interface 'g') to the controller to represent the Path Traffic Ratio API.

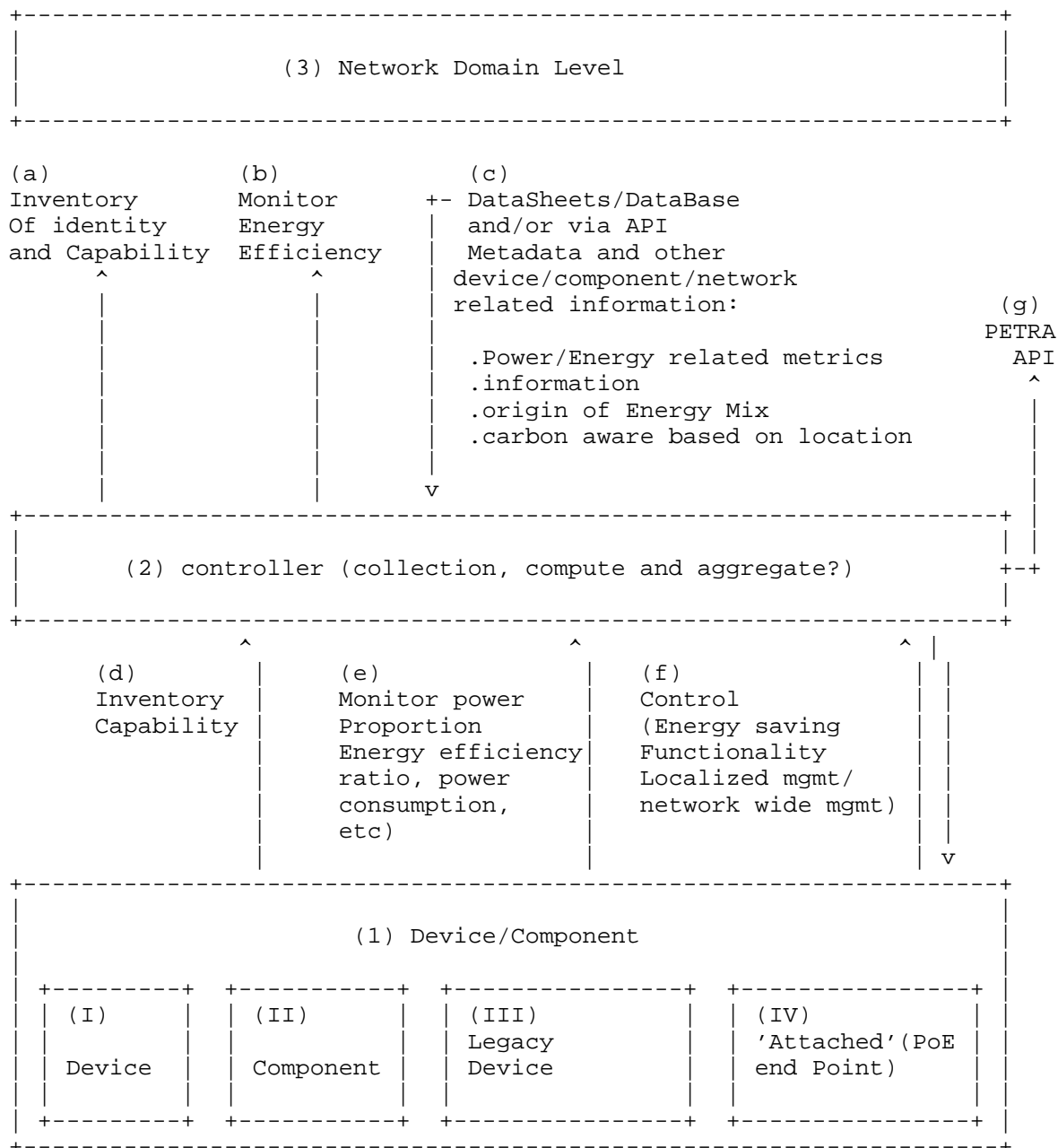


Figure 1: PETRA Integration in Energy Management Framework

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